

# Two-phase spectral modelling of 1E1740.7-2942

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## Abstract.

Combined ASCA and SIGMA data of 1E1740.7-2942 during its standard state (September 1993 and 1994) were fitted with two-phase models (ISMBB [8,9] and ADAF [7,3]). In ISMBB's, the radius of the spherical hot ( $T_e = 150 - 200$  KeV) corona lies between 200 - 250 km where it joins the classical inner disc. The disc radiates 40 % of the total luminosity (with  $\dot{M} = 0.017\dot{M}_{Edd}$  of  $10M_\odot$ ). ADAF's need an extra component to reproduce the soft part of spectrum. However, the origin of the soft excess remains somewhat uncertain, although special care was taken in the background elimination.

## INTRODUCTION

1E1740.7-2942 is the famous jet-source (micro-quasar, Great Annihilator) close to the Galactic Center, observable in the cm/mm and X/Gamma-ray wavelengths [11,1,5,6,10,2,12]. During the last few years, new tools for modelling of X-ray data have been developed. These include two-phase sombrero models ISMBB's [8,9] and ADAF's (advection dominated accretion flows [7,3]). While ADAF's are fixed basically by  $\dot{M}$  (mass transfer rate), ISMBB's have more freedom to fit observations.

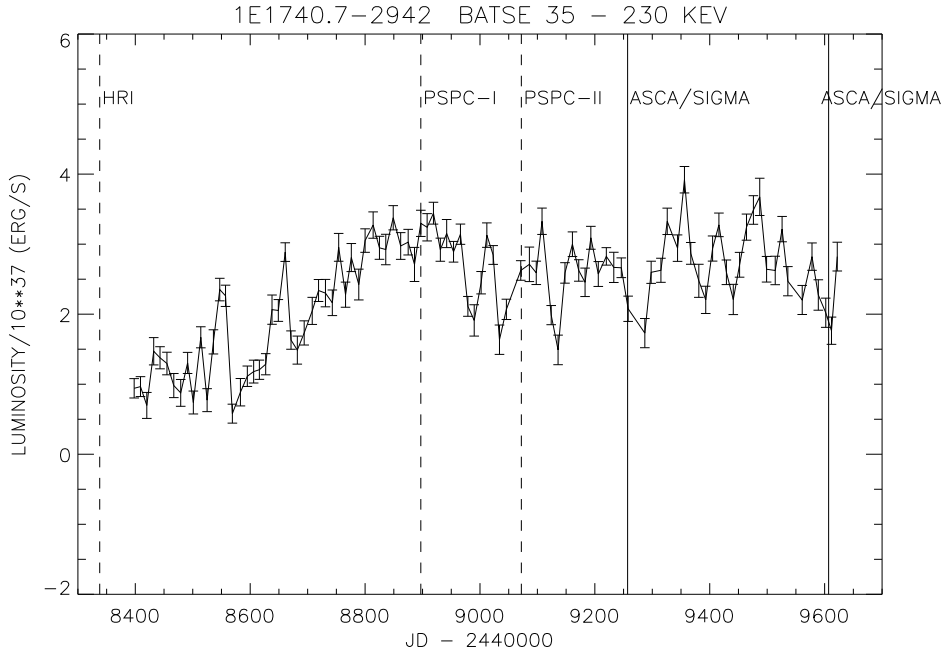
We used ASCA archive data and SIGMA hard X-ray observations (Sept 1993 and 1994) to explore 1E1740.7-2942 with the help of these models (see Figure 1). Simultaneous BATSE results were used for comparison. The near-by background in ASCA images was carefully analysed and subtracted.

## ISMBB AND ADAF MODELS

The hot phase of ISMBB was handled as a pure spherical thermal pair plasma (defined by  $T_e$  and  $\tau_e$ ), although the background plasma (protons) and non-thermal electrons can be included in the treatment. To solve self-consistently the pair balance, the energy balance and the radiative transfer equations, the iterative scattering method (ISM) was used ([8]). The source of soft photons is the classical disc black body radiation with radial temperature-dependence  $T(r) = T_{bb}(r/R_{in})^{-3/4}$ . The disc is allowed to reach inside  $R_{in}$  (where  $T$  is assumed constant), but all our fits converged to the case where the radius of the hot phase equals to  $R_{in}$ . The radiatively heated reprocessed radiation is included in the disc black body, increasing the disc luminosity typically by 20 %. The solution was found running the models and the input data under XSPEC of the XANADU software (see Figure 2 and Table 1).

Several ADAF models were computed around the intermediate state [3] with  $\alpha = 0.3$  (viscosity parameter),  $\beta = 0.5$  (magnetic pressure parameter),  $m = 10$  (mass in solar units) and  $\dot{m} = 0.11$  (mass transfer rate in Eddington units with efficiency 0.1,  $\approx m_{crit}$ ). These models are too luminous by a factor of 4 which can be easily accounted for by slightly reducing the parameters (the luminosity is proportional to  $\alpha^2 m \dot{m}$ ). The  $\dot{m}$ -value from ISMBB-fits is also smaller.

Figure 3 shows the fit with a model having transition radius  $R_{TR} = R_{in} = 10$  (in



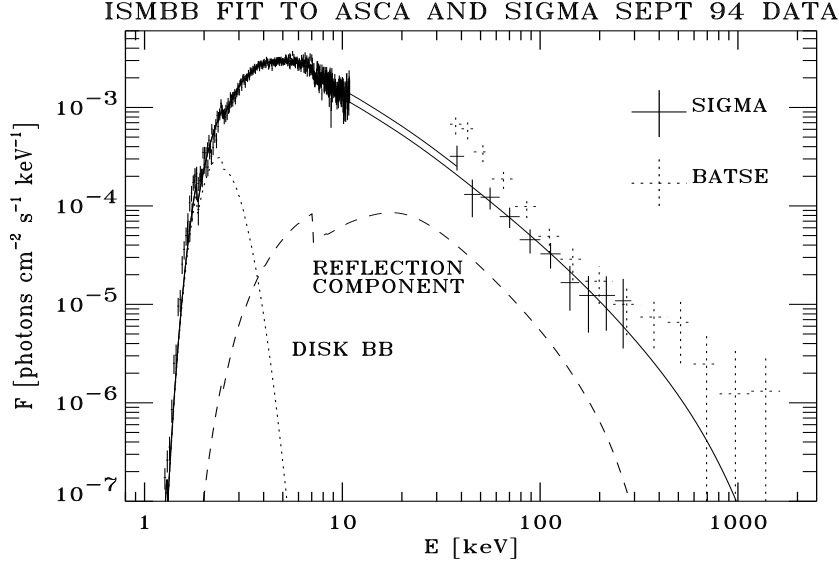
**FIGURE 1.** BATSE light curve of 1E1740.7-2942 showing the dates of the observations discussed in the text.

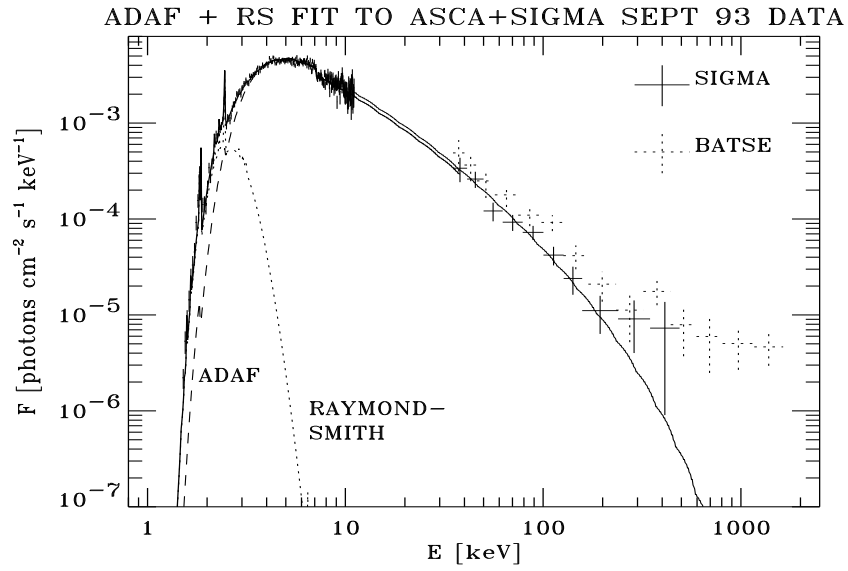
**TABLE 1.** ISMBB and ADAF fits to the standard state of 1E1740.7-2942

PARAM	ISMBB 94	ISMBB 93	ADAF-1 94	ADAF-1 93
$N_H$ ( $10^{22}$ cm $^{-2}$ )	12.3	12.3	15.7	16.8
$kT_{bb}$ (KeV)	0.25	0.23	$\approx 0.2$	$\approx 0.2$
$T_e$ (KeV)	200	150	$\approx 110$	$\approx 110$
$\tau_e$	0.7	1.3	$\approx 2.1$	$\approx 2.1$
$\cos(\text{incl})$	0.95	0.95	0.87	0.87
$R_{in}^a$	7	8	10	10
$L_{total}$ ( $10^{37}$ erg/s)	4.5	5.6	3.5	4.4
$L_{disc}/L_h$	0.82	0.55		
red. $\chi^2$	1.13	1.12	1.17	1.16

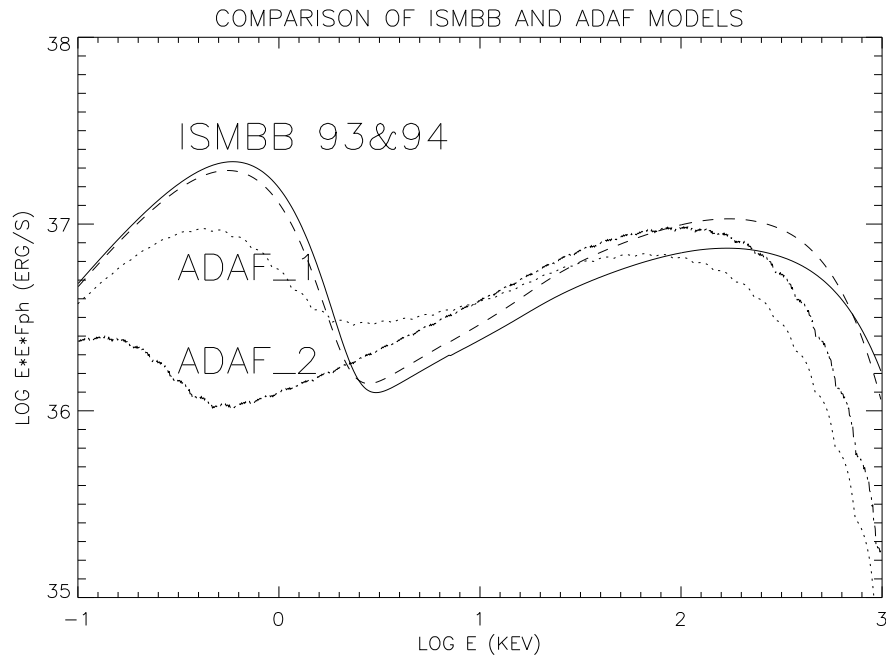
<sup>a</sup>  $R_{in} = R_c = R_{TR}$ , in  $R_{Sch}$  units of  $10M_\odot$

Schwarzschild units). For a smaller radius the spectrum is too soft, while for a larger one the disc spectrum lies totally outside the ASCA-range (see Figure 4 where the models are compared). Even the model with  $R_{TR} = 10$  needs an extra component, in Figure 3 the excess was modelled by a thin plasma (Raymond-Smith) with emission measure of  $1.1 \times 10^{62}$  cm $^{-3}$  and  $T = 0.28$  KeV. Using the Sedov-model, we can speculate that a shocked young ( $\leq 1000$  years) supernova remnant, expanding in a dense ( $\geq 10^{2.5}$  cm $^{-3}$ ) medium and originated in a relatively quiet explosion ( $E_T \leq 10^{48.5}$  erg), can explain these values and the small size (point source in the ROSAT HRI-image).

**FIGURE 2.** ISMBB fit to the September 1994 data. BATSE results are overplotted.



**FIGURE 3.** ADAF model ( $R_{TR} = 10R_{Sch}$ ) fit to the September 1993 data. BATSE results are overplotted.



**FIGURE 4.** ISMBB (1993 and 1994) and ADAF ( $R_{TR} = 10$  and 100) models.

## CONCLUSIONS

The standard state spectrum of 1E1740.7-2942 can be fitted with the ISMBB models. The disc has an inner radius of 7 - 8 Schwarzschild radii of  $10M_{\odot}$  black hole radiating with  $L_{disc} = 2.2 \times 10^{37}$  erg/s, corresponding to the mass transfer rate of  $2.3 \times 10^{17}$  g/s =  $0.017 \dot{M}_{Edd}$  ( $\dot{M}_{Edd} = 10L_{Edd}/c^2 = 1.39 \times 10^{18} M/M_{\odot}$  g/s, using efficiency of 0.1). Inside  $R_{in}$ , the spherical hot corona ( $T_e = 150 - 200$  keV) emits Comptonized radiation with  $L_h = 2.7 \times 10^{37}$  erg/s.

The ADAF models can reproduce the overall spectral shape and luminosity, provided that the total mass, the mass transfer rate and the viscosity parameters are properly selected. For small values of  $R_{in}$ , the ADAF hot flows are somewhat too cold and the disc spectrum too shallow (see Figure 4). However, it is possible that the soft excess has some other origin we missed (a local excess in the background, circumstellar scattering dust, young SNR in a dense medium, ...), but this can be decided only with future observations having a higher spatial resolution (like AXAF).

An important test for the nature of the soft excess may be the observed ROSAT count rates [4]. The ISMBB models of Table 1 predict 2.5 times higher and 0.8 times lower PSPC and HRI count rates, respectively. If the disc is removed, the predicted count rates are reduced by a factor of 3. However, if an anticorrelation between the soft and hard luminosities exists, a part of the difference can be due to a real variability (see Figure 1).

## REFERENCES

1. Bally J. and Leventhal M. 1991, Nature 353, 234.
2. Churazov E., Gilfanov M. and Sunyaev R. 1996, ApJ 464, L71.
3. Esin A.A, McClintock J.E. and Narayan R. 1997, astro-ph/9705237.
4. Heindl W.A., Prince T.A. and Grunsfeld J.M. 1994, ApJ 430, 829.
5. Mirabel I.F. et al. 1991, Astron.Astrophys. 251, L43.
6. Mirabel I.F. et al. 1992, Nature 358, 215.
7. Narayan R. 1996, ApJ 462, 136.
8. Poutanen J. and Svensson R. 1996, ApJ 470, 249.
9. Poutanen J. 1997, private comm.
10. Sheth S., Liang E., Luo C., 1996. ApJ 468, 755.
11. Sunyaev R. et al. 1991, ApJ 383, L49.
12. Vilhu O. et al. 1997, Proc. 2nd INTEGRAL workshop 'The Transparent Universe', ESA SP-382, p.221, astro-ph 9612194.